Electronics Testing for TeV Gamma-ray Telescopes

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Abstract

Gamma-ray astronomy with a ground-based telescope involves the detection of gamma radiation through its visible interactions with the Earth's atmosphere. As with other visible light telescopes on the Earth's surface it makes sense to put a ground-based gamma-ray telescope in an environment with a thin, dry, and stable atmosphere, namely a high desert. The detection and processing of these visible signals, particularly over the sort of large temperature range expected in the telescopes' operating environment, then represents one of the immediate challenges in the design of a ground-based gamma-ray telescopic array such as the Advanced Gamma-ray Imaging System (AGIS). In this study two of the characteristics of signal detection, namely triggering efficiency and trigger width, are studied for our electronics over an expected operating temperature range of -20°C to 50°C. Using uniform incoming pulses in a thermally controlled operating environment it was found that the range of threshold voltages where efficient triggering narrowed slightly as temperature increased while the width of the trigger declined more noticeably.

Introduction

The Basic Mechanics of Ground-Based Gamma Ray Astronomy

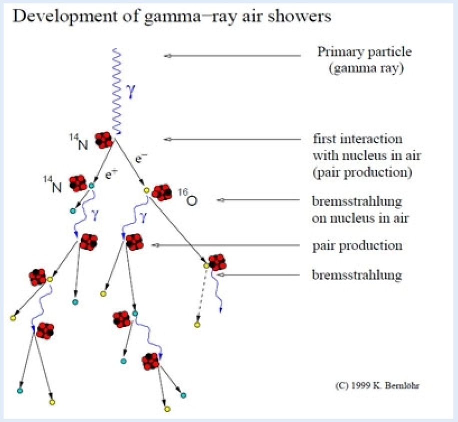

Figure 1 – An event in an extensive air shower from an incident gamma ray.

Energetic gamma rays interact with the atmosphere to produce energetic particle / anti-particle pairs. These pairs then proceed to produce showers of highly energetic particles which travel towards the ground with a velocity greater than the speed of light in the atmosphere.

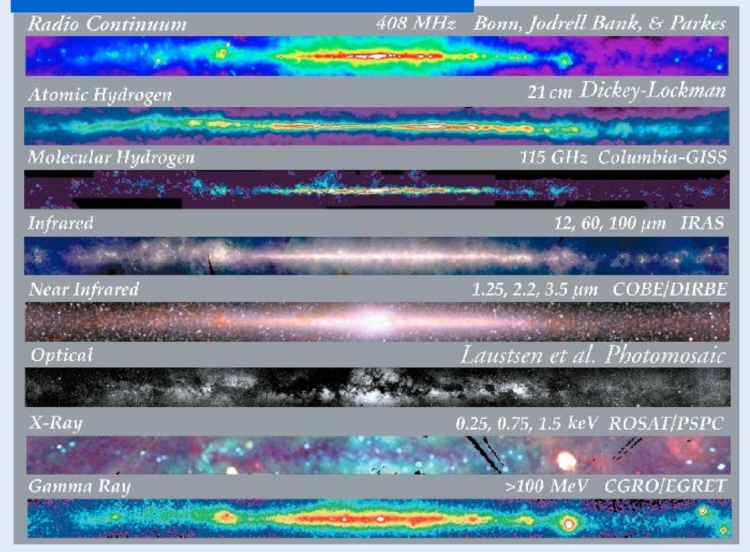

Figure 2 – Multi-wavelength image of the Milky Way. Note the different structures which can be resolved at different wavelengths.

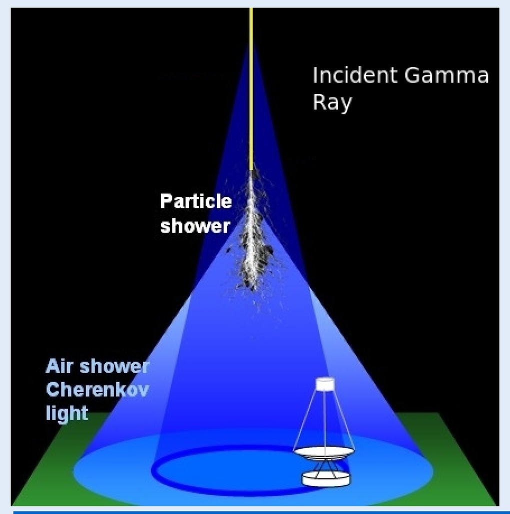

Figure 3 – Cerenkov light detection from a ground-based telescope array such as AGIS.

Introduction - cont.

An advantage with a ground-based telescope is that gamma radiation can be detected, albeit indirectly from visible light produced by an air shower, kilometers away from the initial gamma ray photon. This behavior allows for a large potential area which can be illuminated by single incident gamma ray photons. This in turn has provided the motivation for the construction of arrays of visible light telescopes, such as AGIS, which can detect incoming gamma radiation in the energy range of 100 GeV to 100 TeV through the detection of Cerenkov light.

As pixels are illuminated by a flash of Cerenkov radiation a signal is registered in a set of Photo-Multiplier Tubes (PMTs), which in turn send a potential event signal to the TARGET (TeV Array with GSa/s sampling and Experimental Trigger) as shown:

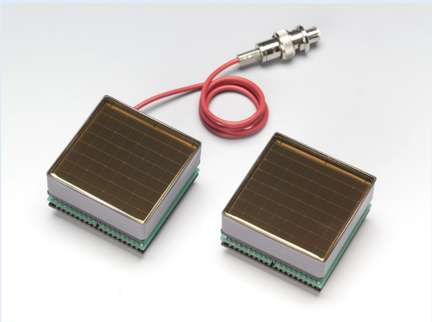

Figure 4 – A multi-anode PMT

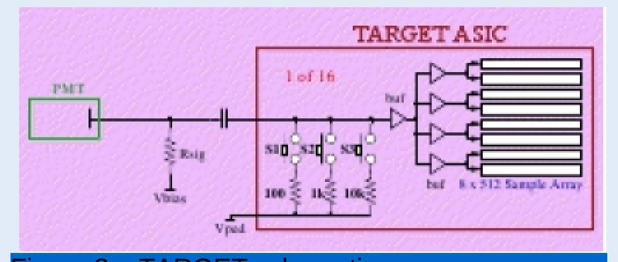

Figure 3 – TARGET schematic

Experimental Setup

Trigger Efficiency

This testing was accomplished by sending repeated uniform pulses at a set frequency from a signal generator into the TARGET chip, then the TARGET chip was timed on how long it took to register a predetermined number of events. The efficiency was then calculated on the ratio of time it took to register these set number of events to the time it would take to register these events given 100% triggering efficiency.

Trigger Width

Using an oscilloscope the mean width of the trigger pulse, along with its associated error, was measured over the operating temperature range of -20°C to 50°C.

Results

Trigger Efficiency

The TARGET chip was placed in a thermal chamber to change the temperature in 10°C increments from -20°C to 50°C. For a given temperature the threshold voltage, the signal voltage at which the TARGET will trigger, was varied to study its relation to trigger efficiency.

In general the the range of threshold voltages where the TARGET chip will trigger efficiently contracts slightly as the temperature of the TARGET chip's environment increases, albeit by a small amount.

Trigger Width

The width, duration, of the trigger signal does narrow as the TARGET chip's temperature is increased.

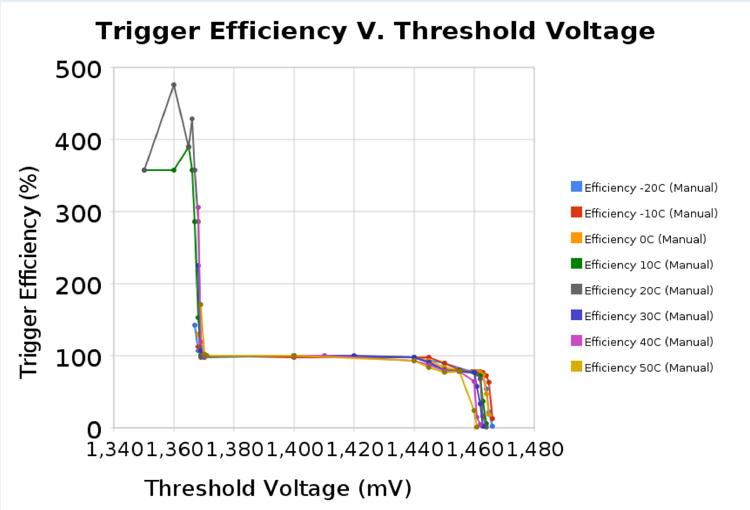

Figure 4 – Trigger efficiency

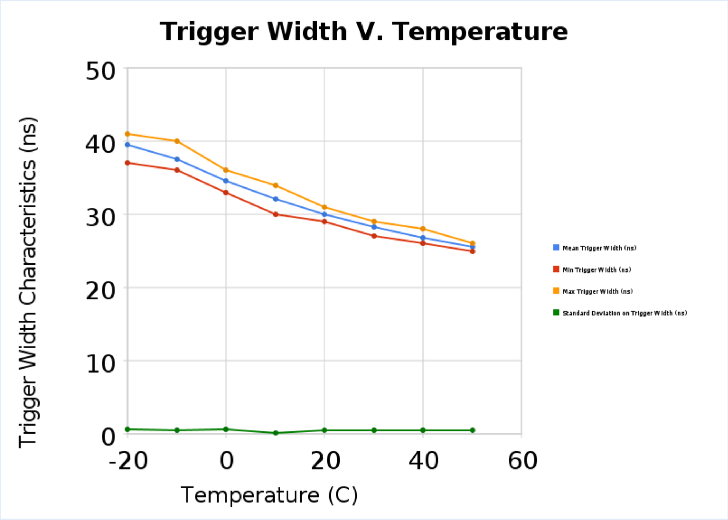

Figure 5 – Trigger width

Furture Directions

Currently work is being done to characterize the TARGET's behavior to these same conditions, but with a negative voltage pulse as opposed to a positive pulse.

References

S. Funk, J.A. Hinton (2009). AIP Conference Proceedings
H. Tajima, et al (2009). Report of Camera Working Group, AGIS Collaboration

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